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HELIUM MASS SPECTROMETER LEAK DETECTOR MODIFIED TO SENSE NEON FOR CRYOGENIC LEAK CERTIFICATION*

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HELIUM MASS SPECTROMETER LEAK DETECTOR

MODIFIED TO SENSE NEON FOR CRYOGENIC LEAK CERTIFICATION

by

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Abstract

The modification of mass spectrometer leak detectors for sensing neon is described. The installation of a speed choke allows leak detecting with a minimum detectable leak of $< 2 \times 10^{-9}$ ATM CC/SEC/DIV. This is usable in areas with high helium background and on vacuum systems contaminated with helium where 85% of the most sensitive scale cannot be achieved with helium as the trace gas.

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Introduction:

Certification of welds and seals for the Superconducting Tevatron Accelerator System at Fermilab (i.e., superconducting magnets, helium transfer lines, etc.) require leak detectors to be calibrated per AVS Standard 2.1 Test Procedure minimum detectable leak (MDL). The MDL as required is $<2\text{x}10^{-9}$ ATM CC/SEC/DIV helium. The leak detector's output meter must be less than 85% on the most sensitive scale while open to the vacuum vessel under test. The problems of high helium background areas and vacuum vessels contaminated with helium prevent normal leak detecting. The modification of the leak detectors to sense neon allow leak detecting to continue in a high helium environment.

The installation of a speed choke gives the operator two known sensitivities. One sensitivity for normal leak detection and the other for extra fine leak detection with a normal clean-up time. A leak detector with both the neon modification and the speed choke permits leak detection sensitive enough to certify cryogenic helium vessels.

Helium Contamination

The Tevatron Accelerator is located 25 ft. underground in a concrete tunnel approximately four miles in circumference. The Tevatron is made up of approximately 1,000 superconducting magnets and associated cryogenic components connected to form the accelerator ring. The final leak check certification on the Tevatron required several leak detectors connected to a multichannel strip-chart recorder. The liquid helium and liquid nitrogen systems were pressurized with helium while leak detectors sensed the vacuum jacket and beam tube. Two leak checking problems arose with the system, the residual helium background and the helium absorption contamination of the system.

Occasionally a crew leak checking in one tunnel area would accidently relieve a pressurized volume of helium into the tunnel. A crew in another tunnel area would notice a rise on their leak detector's output meter indicating a false leak or would have erratic output due to helium pockets in the atmosphere. The Tevatron Accelerator has many miles of welds and numerous joints so the possibility of a weld cracking or a seal leaking liquid helium into the vacuum jacket is always present. Many hundred feet of the accelerator are contaminated if there is a rupture. It takes a minimum of two weeks of pumping and/or purging to resume normal leak checking at less than 85% on the most sensitive scale. The magnet test facility and magnet fabrication areas suffer similar leak detection problems.

Neon Characteristics

The selection of neon as the trace gas is important. The contamination of the earth's normal atmosphere with helium (5 ppm), and with neon (18 ppm) is much less than with argon (9,300 ppm). Leak checking with argon in the presence of air leaks would be less sensitive due to the residual argon in normal air. The relative diffusion rates of neon and argon to helium is one-half and one-third respectively. Although neon is more costly, the time saved by eliminating the long pumping and/or purging periods needed to clean up helium systems can more than offset the expense.

Neon Mass Spectrometer

The factors which influence the modification of the leak detectors[1] for neon service are: the strength of the magnet, the physical size of the magnet and the existing electronics. The mass spectrometer parameters are related by the expression:

$$r = \frac{K}{B} \left[\frac{mV}{e}\right]^{1/2}$$

r - radius of curvature

K - constant

B - strength of the magnet

m - mass of the detected ion

e - charge of the detected ion

V - acceleration voltage

Simple algebraic manipulation shows that, by increasing the strength of the magnetic field, the existing spectrometer electronics can be used without any modification. We did not have to change or adjust the baffle configuration from accelerator to collector.

The normal procedure for tuning with helium requires the standard leak to be opened to find the maximum sensitivity due to no background. After the stronger magnet was installed and adjusted to sense neon. The tuning to neon was confusing. When tuning with the neon standard leak open, the background appeared to blend with the neon peak. Scanning the accelerator voltage, from low to high, we found a background was present everywhere but where neon was known to be detected (Fig. 1).

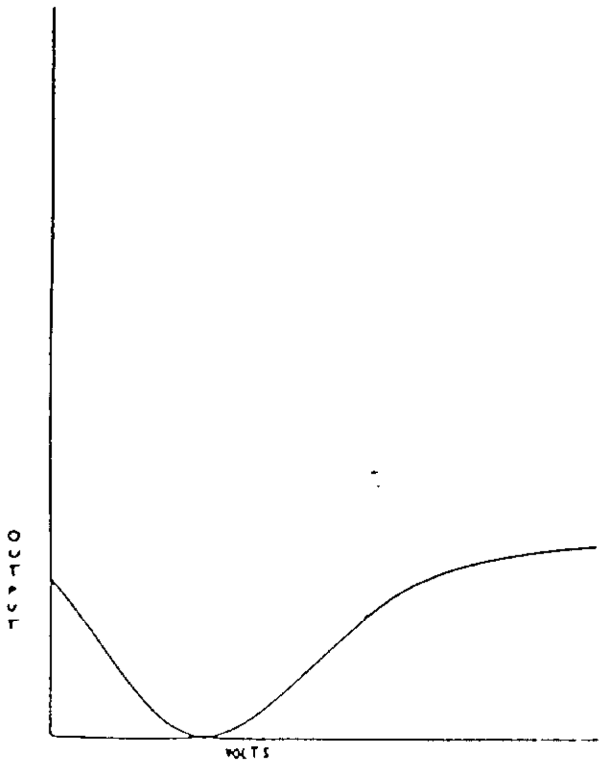

Figure 1

Background: output vs acceleration voltage

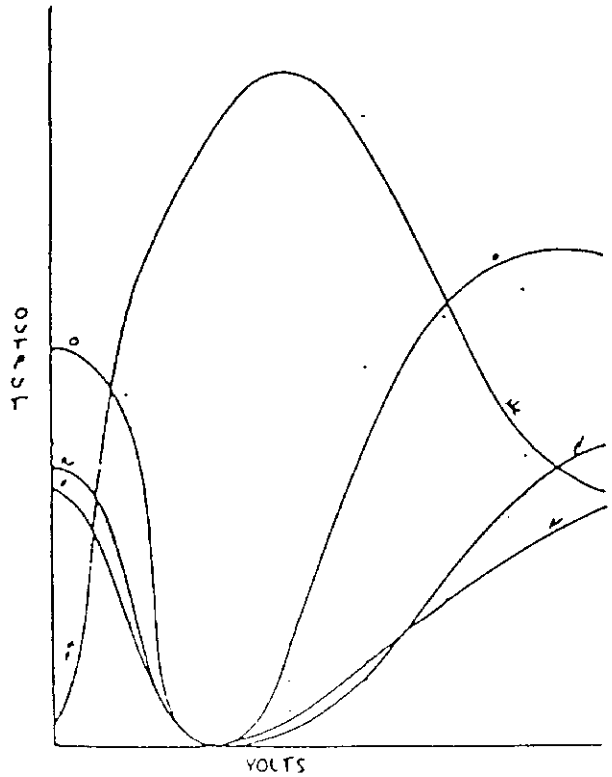

Figure 2

Gases: output vs acceleration voltage

To check the neon standard leak for purity and investigate the background with relation to other gases. We temporarily installed a quadrupole-mass spectrometer near the sensing area in the leak detector. We flowed neon, argon, oxygen and nitrogen through a variable leak into the leak detector. While scanning the acceleration voltage, the output meter reading and acceleration voltage were recorded (Fig. 2). There exists an acceleration voltage which allows only neon to reach the collector. Decreasing the ionization current reduced some of the background. A precise method for tuning to neon evolved from the knowing how to use the background and decreasing the ionizing current when the stronger magnet was installed.

The stronger magnet is physically a larger magnet. Two magnets are necessary for dual operation (one magnet for helium leak detector and another magnet for neon leak detection). We designed a magnet fixture to accomodate either magnet. The operator can change to the other trace gas within minutes when necessary.

Speed Choke

The need for better leak sensitivity was required for some applications. The standard measure of the sensitivity is the product of the internal pressure and gas flow per divisions on the output meter (sensitivity = atm cc/sec/division). The leak detector becomes more sensitive when the flow is reduced. This can be accomplished by either installing a fixed choke, or partially opening the pumping system's isolation valve. The disadvantage of a fixed choke on a large vessel is extremely slow clean-up of tracer gas. The disadvantage of a partially opened isolation valve is recalibration of leak detector to resume certification, after the isolation value is opened for quicker clean-up of tracer gas. To reset a previous sensitivity can become quite tedious.

A removable fixed choke will produce an improved sensitivity when inserted in the pumping system's manifold. Quick clean-up is accomplished by removal of the fixed choke. The fixed choke is returned to the manifold to resume the previous leak detecting.

A gate valve with a small hole drilled in the seat plate was installed at the inlet of the diffusion pump, we used a 5/32 hole to improve the sensitivity by a factor of eight. A gate valve was used to maximize the conductance of the leak detector manifold with the gate valve opened. We called this arrangement a speed choke[2]. An added advantage is two known sensitivities are always available to do normal and very sensitive leak detecting.

Neon Certification Capabilities

The AVS standard 2.1 test procedure requires a strip chart be used to determine a minimum detectable signal (noise and drift). The minimum detectable signal (MDS) and sensitivity are combined to get the minimum detectable leak (MDL). The MDL of the neon mass spectrometer leak detector without speed choke was 2×10^{-9} ATM CC/SEC/DIV. The diffusion rate of neon is half that of helium. The equivalent helium MDL therefore is 4 x 10^{-9} ATM CC/SEC/DIV with neon as trace gas, this is acceptable for a gross leak check. The use of the speed choke with a factor of eight improved sensitivity allows our equivalent helium MDL to drop to $<$ 2 x 10^{-9} ATM CC/SEC/DIV with neon as the trace gas.

Summary

The problems for leak detection inherent to superconducting cryogenic systems are a high helium background and helium contaminated vacuum vessels. The neon mass spectrometer leak detector with a speed choke is available for locating leaks and certification of vacuum vessels when helium contamination becomes a problem. This leak detector can be useful in large vacuum vessels contaminated during leak checking with helium. The operator can convert the leak detector in minutes to neon to resume tests. It is also useful in situations where a residual gas with a similar charge-to-mass ratio as helium interferes with leak detection.

References

[1] F. Juravic, Fermilab's Technical Memo TM-1072 (1982)

[2] F. Juravic, Fermilab's Technical Memo TM-1233 (1983)